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With the author's compliments

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On the Glacial Deposits *of* West Cheshire, *together with* Lists *of the* Fauna *found in the* Drift *of* Cheshire *and* Adjoining Counties.

By W. Shone, Esq., F.G.S.

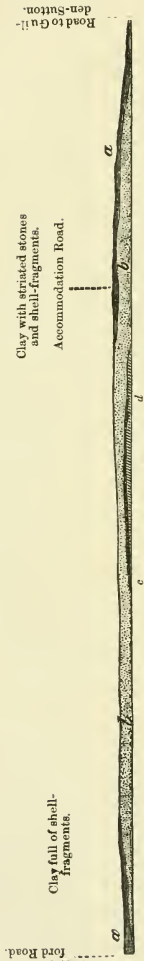
In March 1874, I communicated through Mr. D. Mackintosh, F.G.S., a paper on the "Discovery of Foraminifera, &c., in the Boulder-clays of Cheshire" (Quart. Journ. Geol. Soc. vol. xxx. p. 181). Since that time I have continued my observations, which I now place before the Society.

The extension recently of the Midland Company's line from Mouldsworth to Chester has caused interesting sections of the Drift to be exposed. The accompanying section to this paper exhibits that portion of the line which commences where the road from Hoole to Trafford crosses it, and is continued from that point for two miles and a quarter to a point a little beyond where the road from Trafford to Guilden-Sutton passes under the railway. From the commencement of the cutting at the Newton-road bridge to a spot near the top of Newton Hollows, a distance of half a mile, the Upper Boulder-clay through which it passes contains very few (if any) striated stones, and no shell-fragments, though small rounded gravel is present throughout it.

The cutting varies from 5 to 10 feet in depth up this point, consequently only the upper part of the clay is exposed; its entire thickness at the commencement of the section I estimate at 30 feet. The sand may at intervals be observed to crop out from beneath the clay in a dell which runs parallel to the railway-cutting, called Newton Hollows, proving its (the sand's) continuance beneath the clay throughout this part of the section. I am indebted to Mr. A. Strahan, B.A., F.G.S., for pointing out to me the outcrop of the sand in Newton Hollows. From near the top of Newton Hollows shell-fragments and striated erratics begin to be present, and continue to increase in number and size to where the basement of the Upper Clay resting upon the eroded surface of the Middle Sands is exposed near the bridge where the road from Chester to Trafford crosses over the railway. The characteristics of the Upper Boulder-clay are of the same persistence here as elsewhere over the plains of Lancashire and Cheshire; it is of a reddish-brown colour, broken into rude columnar structure by the cracking of the ground during seasons of drought. The faces of these rude columns are of a bluish-white colour, which is caused by the rain percolating from the surface down these cracks, and washing away, by reason of its slightly acidulated properties, the oxide of iron that colours the particles of the clay. These blue partings are very characteristic of the Upper Boulder-clay.

From the Newton section of the Upper Boulder-clay I have

Section in the Newton cutting of the Chester and West Cheshire Junction Railway.
(Scale about 16 inches to one mile.)



obtained 57 species and varieties of Mollusca, 2 Polyzoa, 26 Ostracoda, 2 Cirripedia, 2 Annelides, 3 Echini, 2 Sponges, and 55 Foraminifera.

The Microzoa were obtained from the sand within the Gastropoda found in the Clay, principally *Turritellæ*, upwards of 1500 of which shells I washed the sand out of, and examined for this purpose.

The Middle Sands were well exposed in that part of the section commencing from the Trafford-road bridge before mentioned, and continued on the north side of the cutting for the third of a mile, and gradually disappearing beneath the Upper Boulder-clay; the junction between the Clay and the Sand was sharp and eroded. The sand was very fine throughout, and contained no shell-fragments, except such as were of the size and roundness of the grains of sand. I examined it repeatedly for microscopic shells, but it yielded none. The shells in the Middle Sands are usually found in the seams of fine shingle which are generally present; in this case, however, though the exposure of the sand was a third of a mile in length, and of an average depth of 25 feet, the sand was uniformly fine throughout. It is again exposed, however, in a sand-pit at Upton, belonging to Sir Philip Grey-Egerton, Bart., F.R.S., a village about a mile and a half north-west of the section. From the Upton sand-pit, Mr. George W. Shrubsole, F.G.S., and myself have, after several years' diligent search, made a small collection of shells, the abundant forms being *Cardium edule*, *C. echinatum*, *Tellina balthica*, and *Turritella terebra*. The shells at the Upton pit only occurred in one seam of small shingle a few yards long and about 18 inches deep. The late Miss Eliza Potts, of Chester, first observed this fossiliferous seam many years ago; it was, however, forgotten,

and rediscovered by Mr. Shrubsole. It is worthy of note that the *Turritellæ* and the other Gastropoda of the Middle Sands do not yield any Microzoa; the sand within them is azoic. Mr. De Rance, F.G.S., informs me that he has examined the sand from within the Gastropoda occurring in the Middle Sands of Blackpool with like results. This fact indicates that the conditions which obtained during the deposition of the Middle Sands were different from those under which the Upper and Lower Boulder-clays were formed; for in these for the most part the Gastropoda are filled with a fine greyish-white sand abounding with Microzoa, though the shells lie imbedded in a matrix of red clay. I shall attempt to give the explanation of this further on.

The shells from the Middle Sands and Gravels are, as a rule, more friable and much more *rolled* than those from the Boulder-clays.

In the section the sand was proved to a depth of 35 feet. There was not even a pebble, much less a boulder, found in it. The conspicuous absence of polished and striated erratics in the Middle Sands and Gravels is a marked feature. This sand is of the same horizon as that which covers the flanks of the Cheshire hills in the neighbourhood of Delamere, in which Sir Philip Grey-Egerton in 1835 and 1836 found marine shells, viz. *Cardium edule*, *Murex erinaceus*, and *Turritella terebra*. Sir Philip Grey-Egerton recently informed me that the pits at Wellington and Norley Bank, from which he obtained these shells (Proc. Geol. Soc. vol. ii. pp. 189, 415), have been long since closed.

The most interesting part of the section was that exposed near the accommodation-road bridge leading to a farm (see figure, p. 384. It is the next after the Trafford-road bridge to cross the line. Here the Lower Boulder-clay was exposed for a distance of 150 yards, and varying from 2 to 5 feet in thickness. It was evident, from the eroded surface of the Lower Boulder-clay at its junction with the Middle Sands above, that it was but a relic of the base of it which was here preserved, for the Lower Clay graduated into the coarse red sand of the disintegrated Bunter Sandstone immediately beneath. I have used the term Lower Boulder-clay; but the word "clay" must not be understood literally, as the stratum, though of the horizon of the Lower Boulder-clay, was composed half of dark red clay and half of coarse red sand from the rock beneath, mingled (but not mixed) confusedly together, especially at the base. No shell-fragments were observed. The erratics, however, abounded, being very much more numerous and very much larger than those in the Upper Boulder-clay before described, although of the same kind of rocks in both. The boulders in the Lower Clay consisted principally of Eskdale granite and Ennerdale syenite (identified by Mr. Mackintosh), decomposed greenstone, porphyry, Silurian grit, and (more rarely) Carboniferous Limestone, Millstone Grit, Keuper sandstone, gypsum, &c. Nine tenths of the erratics were polished and striated, the majority on two or more sides, a few only on one side, and striated along the longer axis.

The Lower Boulder-clay of Dawpool, Cheshire, described by Mr.

Mackintosh (Quart. Journ. Geol. Soc. vol. xxviii. p. 388), is not exposed at the base, and therefore cannot be compared with this section; but Mr. T. Mellard Reade, F.G.S., in his excellent paper on the "Drift-beds of the North-west of England" (Quart. Journ. Geol. Soc. vol. xxx. p. 27), describes the Lower Boulder-clay of Liverpool as possessing very similar characteristics.

The Fauna of the Drifts.

Having briefly noted the physical characteristics of these drift-deposits, the still more interesting subject, the fauna, remains to be discussed. The Upper Boulder-clay of the Newton section has yielded a great number of species, not, however, because the shells are more abundant than usual, but in consequence of the extent and duration of the exposure. The period of collection extended over about five years, and all the specimens have been picked from the clay by myself, with the exception of one *Natica sordida*, found in my presence by J. B. Manning, Esq., Constable of Chester Castle. Some thousands of fragments were thus obtained, which have been submitted from time to time to J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.G.S., who has examined and named them. I cannot sufficiently express my thanks to that gentleman for his uniform courtesy and kindness in having undertaken so much difficult and tedious labour.

Of the fifty-six species and varieties which occur in the Upper Boulder-clay of Newton, the following are known to be living in Arctic and Scandinavian seas, but are not as yet admitted to be living on the British shores:—

Leda pernula.
Astarte borealis.
Tellina calcarea.
Dentalium striolatum.
Natica affinis.
Admete viridula.
Pleurotoma pyramidalis.

The following Mollusca found at Newton are living in British seas, but belong to the northern type of our fauna, as they inhabit Arctic and Scandinavian seas in common with our own:—

Mytilus modiolus.
Cyprina islandica.
Astarte compressa, var. striata.
Lacuna divaricata.
Buccinum undatum.
Trophon clathratus, var. truncata.
Pleurotoma rufa.
—— turricula.

The following Mollusca found at Newton are living in British seas, and belong to the southern type of our fauna:—

Arca lactea.
Venus chione.
Natica sordida.

The remaining thirty-eight species found at Newton are not pronounced either northern or southern forms, and do not therefore indicate any particular climatic conditions.

In the Middle Sands at Upton, out of twenty-three species found jointly by Mr. Shrubsole and myself, two are Scandinavian, *Astarte borealis*, *Dentalium striolatum*, and four British, but of northern type, viz. *Mytilus modiolus*, *Cyprina islandica*, *Buccinum undatum*,

and *Trophon clathratus*, var. *truncata*. The remaining seventeen species are of no special interest.

From the Lower Boulder-clay of Dawpool, Cheshire, out of thirty-five species, the following are Arctic and Scandinavian forms :—

Leda pernula.	Natica affinis.
Astarte borealis.	Fusus despectus.

The following are British shells of northern type :—

Mytilus modiolus.	Trophon clathratus, var. truncata.
Cyprina islandica.	Pleurotoma rufa.
Lacuna divaricata.	—— Trevelyana.
Buccinum undatum.	

The remaining twenty-four species are of no special interest.

Dr. Gwyn Jeffreys, in the notes attached to the lists of the foregoing Mollusca from the Upper Boulder-clay of Newton, Middle Sands of Upton, and the Lower Boulder-clay of Dawpool, Cheshire, says, "The fauna is Scandinavian, with the exception of *Arca lactea*, *Venus chione*, and *Natica sordida*," the southern species which occur in the Upper Boulder-clay of Newton.

The Ostracoda in the sand within the shells of the Gastropoda from the Boulder-clays of Dawpool, Newton, and Liverpool were named by the Rev. H. W. Crosskey, F.G.S., and he states that "the group could not as a whole be called a decidedly Arctic one ; but it has a generally northern character, and quite agrees with your description of the fauna," viz. boreal.

The Foraminifera do not indicate any special climatic conditions. They are all British species, the whole of which have been found by Mr. J. D. Siddall, Chester, and my mother, Mrs. Shone, in the estuary of the Dee.

It is of importance to note that the whole of the fauna from the drifts of this district, whether of Mollusca, Ostracoda, or Foraminifera, belong to littoral or sublittoral species, the commonest shore-forms being the most abundant ; so persistent is this littoral character of the fauna that the question naturally arises, Are the localities from which they are obtained the sites of ancient raised sea-beaches ? This query opens out the whole subject of the mode of occurrence and condition of the shells. Mr. Reade, in the paper before referred to (Quart. Journ. Geol. Soc. vol. xxx. p. 31), suggests tidal currents as the principal means by which the shells were distributed. I am of the same opinion, that currents did distribute the shells in the *Middle Sands and Gravels*, because they occur in the *bands of fine shingle*, showing that they have been *sorted* according to *their weight* ; also it is worthy of note that the Gastropoda are consequently not filled with *fine sand*, but with the *coarse* sand in which they lie *imbedded*, which on examination has *never* yet yielded Microzoa. Then current bedding is very frequent, especially where shingle bands occur in the Middle Sands ; and the shells are more rolled than in the Boulder-clays. The fragmentary condition of the shells, and the fact that the wo valves of the bivalve Mollusca are never found united either in the clays or the sands, are so well

known as hardly to require mention. The condition in which Mr. Reade has described the Mollusca as occurring in the Liverpool Boulder-clay is so exactly similar to that in which the shell-fragments occur in the Boulder-clays of Newton and Dawpool that I might copy his remarks word for word. I shall therefore simply refer to his paper (Quart. Journ. Geol. Soc. vol. xxx. p. 31).

With regard to the shells in the Boulder-clays, all observers are agreed that they are not *in situ*, and that they have been transported; but how?

I think that the Boulder-clays bear every evidence of deposition in still water, the particles which compose them being for the most part very fine. For instance, if a piece of Boulder-clay be dissolved in a test-tube filled with sea-water, and then shaken up, it is some time before the fine unctuous mud is redeposited. I think this is a very important fact, when we consider that the Upper Boulder-clay for the most part is spread out in one uniform sheet over the lowlands of Lancashire and Cheshire from the sea to a height of some 500 or 600 feet. I cannot imagine currents at once strong enough to sweep along the shells from the then existing beaches, and at the same time allowing the finest particles of the clay to be deposited. Again, the Gastropoda throughout this clay are usually filled with the very finest greyish-white sand full of Microzoa; would not these currents in rolling them along have swept out this fine greyish-white sand and replaced it with the red Boulder-clay in which they lie imbedded? as it is, however, those filled with Boulder-clay are the exception, instead of being the rule. This argument is also equally applicable to those who maintain that the Upper Boulder-clay is derived, together with its shells, stones, striated erratics, and Scandinavian fauna—in short, that it is not a glacial clay at all.

The mode of the transportation of the shells in face of all these difficulties has long been a puzzle. In the early part of 1875 there was a short, but for the time a very severe frost. At the mouth of the Dee there is an island called Hilbre, some five acres in extent; it is distant across the sands about a mile and a half from the Cheshire shore; this space is covered with water at half-tide. The dead shells of the Mollusca, Ostracoda, Foraminifera, &c. which live in the Laminarian zone are cast up and left by the receding tide between the ripple-marks on the sands. The dead shells of the Gastropoda, as they lie in these hollows, get more or less filled with the fine silt containing the Microzoa. The frost was severe enough to freeze the water left in these furrows by the receding tide; consequently the Gastropoda filled with this silt, the broken shells, &c. were enclosed in thin sheets of ice, which were broken up on the return of the tide, and such as were cast ashore on Hilbre Island were piled together and frozen into blocks. When the thaw commenced it set these blocks free. Charged with the Gastropoda and broken shells, these tiny ice-rafts floated short distances away, distributing as they melted their load of broken shells, and casting the silt-filled Gastropoda over the mud-flats of the delta of the Dee.

I do not think I can offer a better explanation than this of the

manner in which the shells were distributed in the Boulder-clays, and how the Gastropoda filled with silt containing Microzoa are found in a matrix of red clay. That the Gastropoda so filled are spread over a wide area I am able to affirm, having obtained them from various localities in Boulder-clays in Lancashire, Cheshire, Flintshire, Denbighshire, Shropshire, Staffordshire, and the Isle of Man. With regard to height above the sea, the Gastropoda containing silt with Microzoa are as common to the Boulder-clay of Macclesfield, which overlies the Middle Sands and Gravels, and that at Arnfield, Cheshire, above 600 feet up on the flanks of the Pennine Chain, as they are at the sea-level in the Lower Boulder-clay of Dawpool*. Among the Foraminifera *Rotalia Beccarii* and *Bulimina pupoides* are the most persistent species, being found in the Gastropoda from the Boulder-clay of Macclesfield and Arnfield to that of all the counties above mentioned. They are two of the most common littoral species of our shores. The Scandinavian facies of the fauna from the Upper and Lower Boulder-clays establishes that the climate would be cold enough for the formation in winter of coast-ice on the then shores, while the employment of ground-ice for the distribution of the shells in the Boulder-clays does away with the difficulty of the deposition of the finer particles of the clay, as the water might be sufficiently still in the depths of the sea for its accumulation, while the ice-rafts from the coasts were floating upon the surface, discharging as they melted their freights of sand, broken shell, gravel, and striated erratics gathered from the more distant beaches. This would account for the fauna being littoral and sublittoral, and of species whose habitats are among seaweeds, rocks, and sands being mingled confusedly together in a common matrix of clay.

The mingling of northern and southern forms together in the drifts demands some explanation. From an analysis of the fauna of these deposits in Lancashire and Cheshire, it appears that northern shells are more common in the clays, and rarer in the Middle Sands and Gravels, while, on the other hand, southern shells are rare in the Clays and more common in the Middle Sands and Gravels. If we turn to the physical aspect of the drift, it will help us to clear up the difficulty. Thus, the Lower Boulder-clay at its junction with the Middle Sands and Gravels is most generally eroded, and bears the marks of having once been far more extensive than at present. The Lower Boulder-clay contains a Scandinavian fauna; is it not therefore more than probable that the Scandinavian shells of the Middle Sands and Gravels have been derived from the Lower Boulder-clay? and thus we have, as at Leylands, *Trophon Fabricii* with *Mactra glauca*, and again, at Macclesfield, *Astarte borealis* with *Arca lactea*. Again, if we examine the gravels, we find them largely composed of the granites, porphyries, limestones, and grits which

* Mr. R. D. Darbishire, B.A., F.G.S., gave me some silt &c. containing Foraminifera which he had gathered from the beach at Gorteen, Connemara, Ireland. My mother, Mrs. Shone, on examining this débris, observed that the fry of the Gastropoda, which abounded in it, were all filled with this Foraminiferal silt, and only awaited the formation of ground-ice on the shore to repeat the phenomenon of the Gastropoda of the Boulder-clays.

occur as striated erratics in the Lower Boulder-clay, the difference, in fact, being that in the Middle Gravels they are rounded and the striæ obliterated, while in the Lower Boulder-clay they are angular, subangular, polished, and scratched. If it be reasonable to derive the gravels chiefly from this source, it is equally reasonable to derive the Scandinavian shells found in the Middle Sands from the same source.

Also if we examine the junction between the Upper Boulder-clay and the Middle Sands and Gravels, the latter are very much eroded, so much so that they form dome-like masses with the clay filling up the hollows. The Middle Sands and Gravels contain southern shells; what, therefore, more likely than that the southern forms, which are very rare in the Upper Boulder-clay, should have been derived from the Middle Sands, and so explain away the apparent inconsistency of such shells as *Admete viridula*, *Natica affinis*, and *Pleurotoma pyramidalis* occurring in the Upper Boulder-clay of Newton side by side with *Area lactea*, *Venus chione*, and *Natica sordida*?

At the Dawpool Cliffs the River Dee is carrying away the Lower Boulder-clay, and its Scandinavian fauna is being mingled and redeposited in the delta with the shells of recent species inhabiting the estuary.

We appear, therefore, to have, as suggested by Prof. Hull, F.R.S., a threefold division of the Glacial drift, although I think it is to be regretted that the terms Lower Boulder-clay, Middle Sands and Gravels, and Upper Boulder-clay should have been chosen to express the phenomena of any particular periods, as we cannot but imagine that clays, sands, and gravels were in course of deposition during all these periods, though of course one or other may have locally predominated at specified intervals. I think that Lower Glacial Drift for Lower Boulder-clay, Interglacial Drift for Middle Sands and Gravels, and Upper Glacial Drift for Upper Boulder-clay would be more comprehensive.

In conclusion, I believe we have here evidence of a Glacial age, marked in the lowlands of the west coast of England by the marine Lower Boulder-clay; that it was succeeded by a temperate age, represented by the Interglacial Middle Sands and Gravels*, with their southern Mollusca, as *Area lactea*, *Venus chione*, &c., the boreal forms having been *derived* from the denudation of the Lower Boulder-clay; and, lastly, that in the Upper Boulder-clay we have evidence of a partial return to Glacial conditions like those of the Lower Boulder-clay era, though not so severe, the climate being Scandinavian.

In the following Tables of Foraminifera and Ostracoda, the species marked 1 in the Liverpool column were found by Mr. T. Mellard Reade, F.G.S., and Mr. David Robertson, F.G.S., not in *Turritellæ*, however, but free in the Boulder-clay; those marked * in this column were found by me in the sand from within *Turritellæ* which were sent to me by Mr. Reade (see Quart. Journ. Geol. Soc. vol. xxx. p. 29).

* Mr. D. Mackintosh, F.G.S., has recently, on physical grounds, suggested the Interglacial character of the Middle Sands and Gravels. I rest my opinion, however, more upon the southern fauna.

FORAMINIFERA.

	U. B. Clay, Newton. W. Shone.	U. B. Clay, Liverpool. W. Shone and T.M.Reade.	L. B. Clay, Dawpool. W. Shone.
Cornuspira involvens, *Philippi*	*	*	
Biloculina ringens, *Lamk.*	*	1	*
—— elongata, *D'Orb.*	*		
Triloculina trigonula, *Lamk.*	*	...	*
—— oblonga, *Montagu*	*	...	*
Quinqueloculina seminulum, *Linn.*	*	*1	*
—— bicornis, *W. & J.*	*	*	
—— secans, *D'Orb.*	*	*	
—— subrotunda, *Montagu*	*	*	*
—— agglutinans, *D'Orb.*	*	...	*
—— Ferussacii, *D'Orb.*	*	1	
Lituola scorpiurus, *Mont.*	*		
—— canariensis, *D'Orb.*	*		
Lagena sulcata, *W. & J.*	*	1	*
—— lævis, *Montagu*	*	*	*
—— striata, *D'Orb.*	*	*	
—— semistriata, *Will.*	*		
—— globosa, *Montagu*	*	*1	
—— marginata, *W. & J.*	*	1	
—— lucida, *Will.*	*	*	*
—— squamosa, *Montagu*	*	1	*
Nodosaria scalaris, *Batsch*	*		
—— radicula, *Linn.*	*	...	*
—— pyrula ?, *D'Orb.*	*		
Dentalina communis, *D'Orb.*	*	...	*
Cristellaria rotulata, *Lamk.*	*	*	*
—— crepidula, *F. & M.*	*	...	*
Polymorphina communis, *D'Orb.*	*	*	
—— lactea, *W. & J.*	*	*	
—— compressa, *D'Orb.*	*	1	
—— myristiformis, *Will.*	...	...	*
Uvigerina angulosa, *Will.*	*	*	
Orbulina universa, *D'Orb.*	*		
Globigerina bulloides, *D'Orb.*	*	*	*
Textularia variabilis, *Will.*	*	*	*
—— globulosa, *Ehrenb.*	*		
—— pygmæa, *D'Orb.*	*	*	*
—— difformis, *Will.*	*	*	*
Bulimina pupoides, *D'Orb.*	*	*1	*
—— marginata, *D'Orb.*	*	...	*
—— aculeata, *D'Orb.*	*	*	
—— ovata, *D'Orb.*	*	*	*
—— elegantissima, *D'Orb.*	*	*	*
—— spinulosa ?, *Will.*	*		
Virgulina Schreibersii, *Czjzek*	...	*	
—— spinulosa, *Reuss*	*		
Bolivina plicata, *D'Orb.*	*	*	*
Cassidulina lævigata, *D'Orb.*	*		
—— crassa, *D'Orb.*	*	...	*
Discorbina rosacea, *D'Orb.*	*	*1	
—— globularis, *D'Orb.*	*	*	
Planorbulina mediterranensis, *D'Orb.*	*		

FORAMINIFERA (*continued*).

	U. B. Clay, Newton. W. Shone.	U. B. Clay, Liverpool. W. Shone. and T.M.Reade.	L. B. Clay, Dawpool. W. Shone.
Truncatulina lobatula, *Walker*	*	*1	*
—— refulgens, *Mont.*	*		
Pulvinulina repanda, *F. & M.*	*	*	
Rotalia Beccarii, *Linn.*	*	*1	*
—— nitida, *Will.*	*	*	*
Patellina corrugata, *Will.*	*		
Polystomella crispa, *Linn.*	*	1	
—— striato-punctata, *F. & M.*	*	*1	*
Nonionina umbilicatula, *Montagu*	*	...	*
—— depressula, *W. & J.*	*	*1	*
—— asterizans, *F. & M.*	*	*1	*

OSTRACODA.

The following Ostracoda have been submitted for identification of the species to the Rev. H. W. Crosskey, F.G.S., and G. S. Brady, Esq., F.L.S., F.G.S., to whom my best thanks are due.

	U. B. Clay, Newton. W. Shone.	U. B. Clay, Liverpool. W. Shone.	L. B. Clay, Dawpool. W. Shone.
Cythere pellucida, *Baird*	*		
—— tenera, *Brady*	*	...	*
—— cribrosa, *B., C., & R.*	...	...	*
—— finmarchica, *G. O. Sars*	*		
—— villosa, *G. O. Sars*	*		
—— concinna, *Jones*	*	*	*
—— tuberculata, *G. O. Sars*	*	*	*
—— dunelmensis, *Norman*	*		
—— Whiteii. *Baird*	*		
—— antiquata, *Baird*	*		
—— Jonesii, *Baird*	*	*	
Cytheridea papillosa, *Bosquet*	*	1†	*
—— punctillata, *Brady*	*	...	*
—— Sorbyana, *Jones*	*		
Eucythere argus, *G. O. Sars*	*		
Krithe bartonensis, *Jones*	...	...	*
Loxoconcha impressa, *Baird*	*		
—— guttata, *Norman*	*	...	*
—— tamarindus, *Jones*	*	*	*
Cytherura striata, *G. O. Sars*	*	*	*
—— angulata, *Brady*	*		
—— producta, *Brady*	*		
Cytheropteron latissimum, *Norman*	*		
—— nodosum, *Brady*	*		
—— montrosiense, *B., C., & R.*	...	*	*
Sclerochilus contortus, *Norman*	*		
Paradoxostoma ensiforme, *Brady*	*	...	*
—— flexuosum, *Brady*	*	...	*
—— arcuatum, *Brady*	*	*	

† Mr. T. M. Reade, F.G.S.

Analysis of the principal Collections of Shells from the Drift of Lancashire and Cheshire, also Moel Tryfaen.

Arctic and Scandinavian species not as yet admitted to be inhabitants of British Seas (authority J. Gwyn Jeffreys's 'British Conchology'):—	Moel Tryfaen.	Lower Boulder-clay, Dawpool, Cheshire.	Middle Sands and Gravels. Macclesfield, Cheshire.	Leylands, Lancashire.	Blackpool, Lancashire.	Upton, Cheshire.	Upper Boulder-clay. Newton, Cheshire.	Liverpool, Lancashire.
Leda pernula	r	r	...	...	...	...	v r	v r
Astarte depressa (crebricostata)	v r							
—— borealis	c	c	c	f	c	r	a	c
Tellina calcarea	r	...	...	...	...	...	f	
Dentalium striolatum	v r	...	v r	...	...	v r	f	
Natica affinis	r	r	...	...	...	...	v r	
Admete viridula	...	...	...	...	...	...	v r	
Fusus despectus	...	v r						
Trophon clathratus, var. scalariformis	f							
—— ——, var. Gunneri	f							
—— Fabricii	?	...	...	v r				
Pleurotoma pyramidalis	v r	...	...	...	...	...	f	
	9	4	2	2	1	2	7	2
Northern type of British species which inhabit Arctic and Scandinavian Seas in common with our own:—								
Mytilus modiolus	r	v r	r	f	...	r	f	f
Cyprina islandica	c	f	c	f	f	f	a	c
Astarte compressa	c	...	...	...	...	...	...	r
—— compressa, var. striata	...	...	...	...	...	...	v r	
Saxicava norvegica	...	...	...	v r	...	...	...	v r
Lacuna divaricata	v r	f	...	...	...	...	r	
Natica grœnlandica	...	...	...	...	...	...	...	v r
Trichotropis borealis	v r							
Buccinum undatum	f	f	r	f	f	f	f	f
Trophon barvicensis	v r							
—— clathratus, var. truncata	f	f	f	f	r	r	c	f
Fusus islandicus	...	...	...	...	...	...	...	r
—— gracilis	v r	...	v r	v r				
—— propinquus	...	...	...	v r				
Pleurotoma rufa	v r	...	v r	...	...	...	v r	v r
—— turricula	f	r	f	...	...	...	f	r
—— Trevelyana	...	r						
	11	7	7	7	3	4	8	10
Southern type of British species which inhabit more southern seas in common with our own:—								
Arca lactea	...	...	v r	...	...	...	v r	
Venus chione	...	...	f	r	r	...	v r	r
Natica sordida	...	...	...	...	...	...	v r	
			2	1	1		3	1

In the Tables of Mollusca v r means that 1 to 3 specimens have occurred; r, 3 to 10; f, frequent; c, common; a, abundant; v, very.

I consider Moel Tryfaen to be the oldest of all these deposits, because there are no southern shells mixed with its Scandinavian fauna.

	Arctic and Scandinavian Mollusca.	British Mollusca of northern type.	British Mollusca of southern type.	Number of remaining species found, but of no climatic value.	Total number of species found.
Newton. Boulder-clay	7	8	3	38	56
Liverpool. „ „	2	10	1	31	44
Dawpool. „ „	4	7	...	24	35
	13	25	4	93	135
Upton. Middle Sands and Gravels	2	4	...	17	23
Macclesfield. „ „ „	2	7	2	37	48
Leylands. „ „ „	2	7	1	34	44
Blackpool. „ „ „	...	3	1	18	22
	6	21	4	106	137

From this Table it will be seen that Arctic and Scandinavian Mollusca are more common in the Boulder-clays than they are in the Middle Sands and Gravels. Figures, however, do not give so clear a notion of the importance of the relative absence of many of the Scandinavian species from the Middle Sands and Gravels as may be obtained from a study of the more detailed analysis, where each species may be followed, and its frequency or infrequency throughout the drift deposits observed.

In the accompanying lists of the Mollusca, the Lancashire localities I have taken from the Memoir of the Geological Survey "On the Superficial Geology of the Country adjoining the Coasts of South-west Lancashire," by C. E. De Rance, Esq., F.G.S. I have compared, however, the Blackpool, Leylands, and Liverpool lists of shells with the published lists of R. D. Darbishire, Esq., B.A., F.G.S. (Geol. Mag. vol. ii. p. 298; Quart. Journ. Geol. Soc. vol. xxx. p. 38), and T. Mellard Reade, Esq., F.G.S. (Quart. Journ. Geol. Soc. vol. xxx. p. 27), and I have corrected the errors which occur in the lists of the Survey publication.

I have to thank Mr. Darbishire for correcting his Macclesfield and Moel-Tryfaen lists, published Geol. Mag. vol. ii. p. 298.

The Mollusca from Newton were found by myself.

The Mollusca from Upton were found by G. W. Shrubsole, Esq., F.G.S., and myself.

		U															
—— incrassata, *Ström*	2	1 2	.....	.....	2	.....	v r	r	...	v r							
Pleurotoma nebula, *Mont.*	.....	.....	.....	.....	...	.....	v r										
		U															
—— rufa, *Mont.*	.....	2 3	.....	.....	...	.....	v r	.....	...	v r	...	...	...	v r			
		U															
—— turricula, *Mont.*	.....	2	.....	.....	2	.....	f	r	...	f	...	*	...	f	...	*	
—— Trevelyana, *Turton*	.....	.....	.....	.....	...	.....		r									
—— pyramidalis, *St.*	.....	.....	.....	.....	...	.....	v r	.....	...	...	...	...	...	f			
Cypræa europæa, *Mont.*	.....	.....	3	.....	...	.....	...	.....	...	v r	...	...	...	v r			
POLYZOA.		U															
Salicornaria Cuvieri, *Lam.*	.....	2	.....	.....	...	.....	...	v r	...	...	...	...	...	r			
Lepralia Peachii, *Johnston*	.....	.....	.....	.....	...	.....	...	.....	...	...	...	...	...	v r			

The Mollusca from Dawpool were found by D. Mackintosh, Esq., F.G.S., and myself.

For the list of Mollusca from Lilleshall, Salop, by C. J. Woodward, Esq., see Brit. Assoc. Report, 1865: see also George Maw, Esq., F.L.S., F.G.S., "On the Drift of the Severn Valley," Quart. Journ. Geol. Soc. vol. ii. p. 130; and for the Warrington list, Mr. Paterson, Proc. Warrington Lit. & Phil. Soc.

Mr. De Rance has classed all Mr. Reade's Liverpool localities as Lower Boulder-clay. I have not presumed to alter this; but as Mr. Reade, in his list (Quart. Journ. Geol. Soc. vol. xxx. p. 27), has distinguished the shells from the Upper and Lower Boulder-clays of Liverpool, I have marked them U for Upper and L for Lower Boulder-clay, as they are stated by Mr. Reade to occur.

Prof. Hughes has found the following Mollusca in the Upper Boulder-clay of Denbighshire (Bryncelwy—The Mount, St. Asaph):—

Turritella terebra.	Cardium echinatum.
Littorina litorea.	—— edule.
Dentalium striolatum.	Venus exoleta.
Pleurotoma turricula.	Astarte borealis.
Tellina Balthica.	

Mr. J. F. Bateman, F.R.S., found some Mollusca in Boulder-clay on the site of the Manchester Waterworks, Hollingsworth Reservoir, Mottram in Longdendale, Cheshire, 568 feet above the sea. Mr. Binney, F.R.S., states that the following were the species found:—*Turritella terebra*, *Trophon clathratus* var. *truncata*, *Purpura lapillus*, *Tellina*, 2 sp., *Cardium edule*, and *Cyprina islandica*.

Discussion.

Dr. Gwyn Jeffreys remarked on the interest attaching to the collections made by Mr. Shone, the most important series of such fossils that had been brought together since Mr. Trimmer and Mr. Darbishire worked out the deposits at Moel Tryfaen and Macclesfield. The mixture of the northern and southern species was very noticeable, and would seem to indicate that some of the beds were *remaniés*. *Venus chione* and *Area lactea* are peculiarly southern forms; and yet they occur with others which are found only in so-called glacial deposits. Of the latter those found in Cheshire are of Scandinavian and not truly Arctic type. On the other hand the fossils from most of the Scandinavian Posttertiary beds are peculiarly Arctic species, but do not occur in these West-Anglian beds.

Prof. Ramsay, referring to the section, said that he could not help feeling that these deposits only mark minor phases in a great Glacial epoch. It seemed to him that the presence of shells in the Boulder-clays was strongly opposed to the hypothesis according to which these clays represented a deep moraine, and in favour of the marine origin of the deposits. He asked the author whether he believed that, before the deposition of the beds described, the region had un-

dergone extensive erosion by the agency of a great sheet of ice (he did not mean an ice-cap) coming from the north. He was led to the conclusion that such had been the case by the direction of the glacial scratches in the north of England, which are all approximately N. and S., or more or less towards the mountains of Cumberland. This glaciation was followed by a submergence, during which the Boulder-clays were formed.

Prof. Hughes had been over the ground with Mr. Shone, and testified to the accuracy of his work and the great value of his paper. One inference he was inclined to question, viz. the age of the upper part of the series, which Prof. Hughes considered entirely Post-glacial. He explained all the scratched stones and some of the northern shells in the so-called Upper Boulder-clay of N. Wales and the borders by their having been derived from older glacial beds.

Mr. Belt considered the paper clear, concise, and to the point. Mr. Tiddeman and others had shown that the ice was piled up to the height of 2000 feet above the sea in Lancashire; Prof. Ramsay that it had overridden Anglesey from the north. It could not have moved down nearly parallel to the coast unless the Irish Sea was filled with ice. This ice had left behind it stones from Cumberland and Scotland; along with these and other transported rocks were broken and worn shells, all of which, it was admitted, had not lived where they were now found, but had been brought from some other place. He contended that the same agent that had brought the foreign rocks had brought also the broken shells and mixed together southern and northern species and deep- and shallow-water forms. He said that in America the ice had not only carried up crystalline rocks thousands of feet above their parent bed, but also soft shales; and if it could do this, it could also carry up sea-shells. He referred to the opinion of Prof. Edward Forbes, who had carefully examined the shells in the northern drift, with the object of determining whether they indicated an ancient sea-coast or an ancient sea-bottom, and had come to the conclusion that they did not, but had been transported to their present position from lower levels.

Dr. J. Gwyn Jeffreys inquired as to the height above the sea-level at which these fossiliferous beds were found, and remarked that our notions of deep-sea forms had changed since the time of Edward Forbes.

The Author, in reply to Prof. Ramsay, remarked that the question raised by him as to whether the rock-striations on low grounds were produced by an ice-sheet or not was a very large one. The softness of the rock in Cheshire would seem to account for no striations being found near Chester; but no doubt such markings are older than the oldest deposits referred to in the paper. In reply to Prof. Hughes, he said that the derivation of the Upper Boulder-clay from the Lower Boulder-clay was barely possible; for, as a rule, beneath the Upper Clay there are usually sands and gravels, and the Scandinavian shells must have passed through the Middle Sands and Gravels in order to get from the Lower into the Upper Boulder-clay. The Upper Clay no doubt indicated an ebbing out of Glacial con-

ditions; but still at the base there is a Scandinavian fauna associated with glaciated stones. In reply to Dr. Jeffreys, he stated that the Newton section is situated at about 140 feet above the sea, and at a distance from it of 20 miles. To Mr. Belt he replied that, as Dr. Jeffreys had said, what the late Edward Forbes would have called "deep-sea forms" would not be so regarded now; all the Mollusca and also the Microzoa from these Drift deposits are either littoral or sublittoral species. The shells containing Microzoa also contain very fine silt, which will come out of them even as they fall through the water in a tumbler into which they have been dropped, so that they could not have borne transportation in their present condition. During their descent from the ground-ice, their contents were probably hard frozen within the shells, which would preserve for a time the silt within them from thawing.